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Fuzzy logic and application as a game-based fire disaster mitigation simulation

Astrid Novita Putri[1*], Dinar Anggit Wicaksana[2], Al Halim Thoriq Febrian[3], Sholifudin Hudaf Alvin[4], Aditya Pratama[5]
[1,2,3,4,5] Department of Informatics Engineering, Universitas Semarang, Indonesia

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ABSTRACT

Fire is a disaster that can occur at any time and place, particularly in high-rise buildings with a high level of risk. This study developed an educational game called "Fire Escape", built using Unity 3D and integrated with Mamdani fuzzy logic to provide an interactive learning experience about fire evacuation procedures. This study adopted a Research and Development (R&D) approach utilizing the ADDIE model comprising the stages of Analysis, Design, Development, Implementation, and Evaluation.The game applies a fuzzy logic system to generate action recommendations based on player parameters such as health points (HP), time, and distance. The development results show that the game successfully integrates educational and entertainment aspects through realistic 3D simulation, intuitive controls, and tiered learning scenarios. The implementation of Mamdani fuzzy logic enables adaptive decision-making, enhancing the player's learning experience. This game can be an effective alternative learning medium to improve public understanding and preparedness for fire emergencies in high-rise buildings.

Corresponding Author:

Astrid Novita Putri
Department of Informatics Engineering,
Faculty of Information and Communication Technology, Universitas Semarang, Semarang, Indonesia
Email: astrid@usm.ac.id
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1. INTRODUCTION

Fires constitute a form of disaster that may occur at any time and in any location, particularly within densely populated urban areas containing high-rise buildings, which are especially susceptible to fire hazards [1]. High-rise buildings are often places where large numbers of people gather, and as such, fires in these locations can lead to significant material losses and loss of life [2]. Data from Kompas.id and the official website of the Yogyakarta City Fire Department indicate that the lack of fire protection equipment can increase the number of casualties, especially in buildings such as hotels and other high-rises, posing a serious threat to occupants [3],[4]. Fire prevention and management are crucial, given that fires can cause ecological damage, reduce biodiversity, and disrupt transportation and public health systems [5]. Therefore, efforts to minimize the impact of fires must be supported, one of which is through improving public understanding of self-evacuation procedures in emergency situations [6].

Combining game-based instructional media with layered narratives and situational context decision-making tasks is a very effective way to get users more interested and help them comprehend [7]. This means that educational games could be used in a lot of different ways in fire drills. The Research and Development (R&D) approach was utilized in this study. This method lets you make and test prototypes of simulation games to help people learn more about how to get out of a fire [8],[9]. People think that the R&D process is good for making game prototypes that are fun and interactive for players [10]. In this case, educational games on mobile devices have been shown to be a fun and valuable tool, especially for simulation-based apps like disaster preparedness training [11].

Fuzzy logic is one of the promising strategies for disaster mitigation learning media since it has been found to help users adapt and make better decisions in educational game simulations [12]. The Mamdani method is thought to be the best fuzzy logic method since it can deal with situations that aren't clear, like fire [13]. This study adds Mamdani fuzzy logic to the game as an intelligent part that gives players action instructions that change and adapt based on what is happening in real time during a fire evacuation scenario. The fuzzy system decides what to do depending on factors including HP (Health Points), how long it will take to evacuate, and how close the threat is. This method allows for a more realistic simulation that comes closer to how people make decisions in crisis by applying the min-max inference method [14].

In the past, research has made a number of educational games to help prevent disasters, but not all of them feature realistic and interactive simulations for players [15]. Most of the games that are out there merely give players static information and don't require them to make decisions that could help them be better prepared for an emergency [16]. One problem with earlier research is that they didn't use a 3D simulation-based method that lets people experience what it's like to evacuate a building during a fire.

The study's proposed approach is to make a 3D simulation game that lets people interact with it and practice how to get out of a fire more realistically [1]. This game distinguishes itself from others by offering a more immersive experience and enabling players to make critical decisions in emergencies [6]. The applications of 3D technology are the most advantageous aspect of this study, since it enhances visibility and enables gamers to learn inside a more authentic fire scenario. This study notably differs from others by concentrating on self-evacuation within a multi-story structure, such as a hotel, which presents greater complexity compared to simpler simulation games [2]. The game enhances its educational component by employing Mamdani fuzzy logic to offer players adaptive suggestions based on their performance. For instance, a player may be instructed to sprint to the finish line, assist a non-playable character, or transport a fire extinguisher. This approach enhances the learning experience by making it more engaging and authentic [17].

The goal of this project is to make a game called 'Fire Escape" that will assist individuals learn and practicing how to get out of a burning building. The game helps players get ready for emergencies by teaching them how to escape a building fire and how to make decisions in an emergency.

2. METHOD

Type of Research

This is a research and development (R&D) that focuses on the development of a 3D educational simulation game for hotel fire rescue. The R&D method was chosen because it allows researchers to systematically develop interactive game prototypes, test products, and provide an in-depth learning experience about fire evacuation, so that the resulting product is not only innovative but also effective in achieving educational goals. In this study, researchers will develop learning media in the form of educational games, which require prior validation to determine the level of media feasibility[18]. This research uses the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model, with the following details:

Analysis

This stage includes a needs analysis to identify the needs and problems that exist in fire evacuation education. The researcher conducted research to find out who the target users of this game are, analyze the shortcomings of existing educational games, and collect information about fire evacuation procedures in high-rise buildings. The main focus is to understand the existing problems and determine what is needed, both technically and educationally, so that the developed 3D simulation game can be effective.

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Design
Overall game design process. Researchers create realistic fire storylines and scenarios, and design the game's visual appearance and interactivity. At this stage, researchers also create storyboards to describe player movements in the game, and design a scoring system to evaluate how players make decisions when facing emergencies [19], [20].

Development
At this stage, the technical development of the game was carried out using the Unity Game Engine. Researchers made a first prototype by making a realistic 3D environment and adding assets from the Unity Store and Mixamo. Also, the character control system was made simple to use, and sound effects, animations, and decision-making tools were included to make the simulation more fun. At this point, a scoring and feedback system was also built that let people judge the choices players made during the game.

Implementation
At this stage, the game is being tested with people who are doing research. Researchers test the game on a group of people to receive immediate input on how it feels to play. At this point, researchers look for difficulties that players are having and areas where the game's design and mechanics could be better.

Evaluation
Researchers looked at what the people who played the game said to make it better. The review was based on professional checks of the game's content and design for correctness, as well as user feedback on how easy it was to use and how fun it was to play.

Fuzzy Logic Design

A fuzzy logic approach is used in the game "Fire Escape" to make the player character's decisions more dynamic and lifelike. This method looks at a number of factors, like HP (Health Points), time, and distance, to figure out the best thing to do in a fire emergency. With this method, the game can provide players personalized advice based on their situation, such rushing to the finish line, aiding an NPC, or using a fire extinguisher. This makes the game more interactive and teaches players how to deal with flames.

a. Input Variables
   The three main input variables for this game are as follows:
   1) Health Points (HP)
      a) Show the player's health status
      b) Range: 0–100
      c) Linguistic categories:
         Low (0–40)
         Medium (30–70)
         High (60–100)
   2) Time
      a) Show the remaining mission time for evacuation
      b) Range: 0–300 seconds
      c) Linguistic categories:
         Short (0–100 seconds)
         Medium (80–200 seconds)
         Long (180–300 seconds)
   3) Distance to Target
      a) Represents the distance from the player to the evacuation point or NPC
      b) Range: 0–100 meters
      c) Linguistic categories:
         Near (0–40 meters)
         Far (30–100 meters)

b. Output Variables
   The fuzzy system produces action recommendations with three possible output categories:
   1) Run Directly (Output: 0)
      Prioritizes self-evacuation by avoiding fire hazards and moving toward the evacuation point.
   2) Assist NPC (Output: 1)
      Involves helping a trapped non-playable character (NPC) and guiding them safely to the evacuation zone.
   3) Use Fire Extinguisher (APAR) (Output: 2)

Involves retrieving and using a fire extinguisher to eliminate fire sources and clear the evacuation route.

c. Fuzzy Membership Functions

Membership functions are defined for each input variable to classify their values into relevant linguistic categories.

1) Health Point (x)

$$\mu_{Low(x)} = \begin{cases} 1, & x \leq 30 \\ \left(\frac{40-x}{10}\right), & 30 < x < 40 \\ 0, & x \geq 40 \end{cases}$$

$$\mu_{Medium(x)} = \begin{cases} 0, & x \leq 30 \; atau \; x \geq 70 \\ \left(\frac{x-30}{10}\right), & 30 < x < 40 \\ 1, & 40 \leq x \leq 60 \\ \left(\frac{70-x}{10}\right), & 60 < x < 70 \end{cases}$$

$$\mu_{High(x)} = \begin{cases} 0, & x \leq 60 \\ \left(\frac{x-60}{10}\right), & 60 < x < 70 \\ 1, & x \geq 70 \end{cases}$$

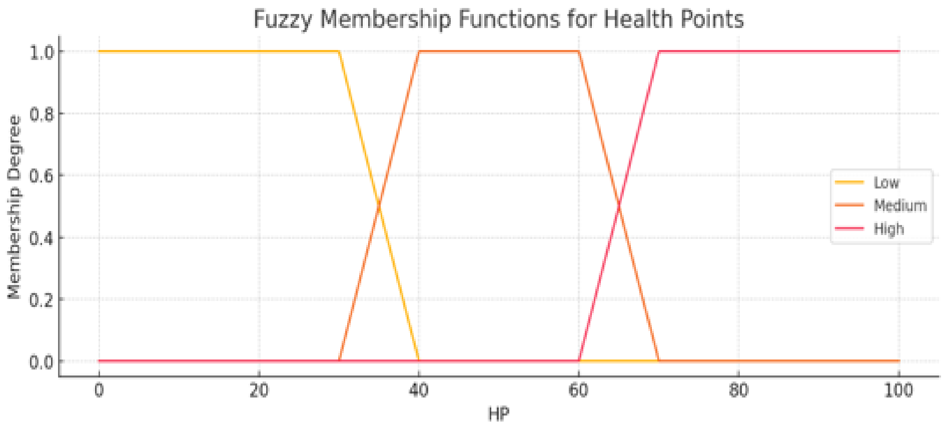

Figure 1. Fuzzy membership function for HP

2) Time (t)

$$\mu_{Short(t)} = \begin{cases} 1, & t \leq 80 \\ \left(\frac{100-t}{20}\right), & 80 < t < 100 \\ 0, & t \geq 100 \end{cases}$$

$$\mu_{Medium(t)} = \begin{cases} 0, & t \leq 80 \; atau \; t \geq 200 \\ \left(\frac{t-80}{20}\right), & 80 < t < 100 \\ 1, & 100 \leq t \leq 180 \\ \left(\frac{200-t}{20}\right), & 180 < t < 200 \end{cases}$$

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$$\mu_{Long(t)} = \begin{cases} 0, & t \le 180 \\ \left(\frac{t-180}{20}\right), & 180 < t < 200 \\ 1, & t \ge 200 \end{cases}$$

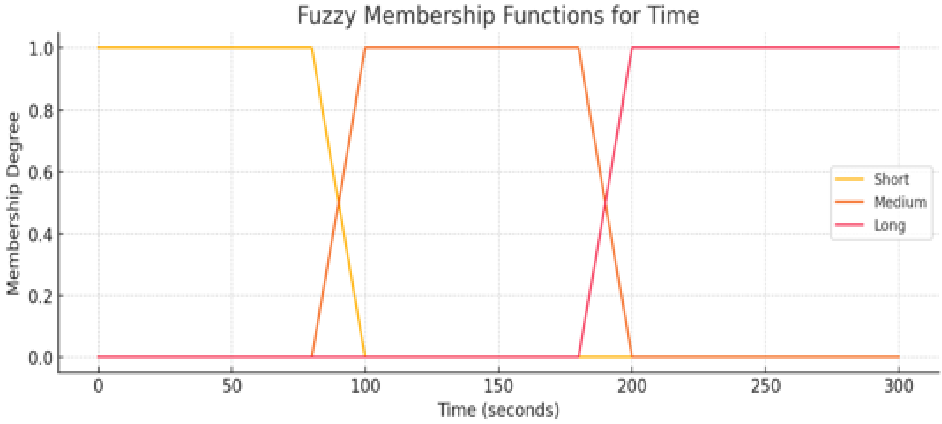

Figure 2. Fuzzy membership function for time

3) Distance (d)

$$\mu_{Near(d)} = \begin{cases} 1, & d \le 30 \\ \left(\frac{40-d}{10}\right), & 30 < d < 40 \\ 0, & d \ge 40 \end{cases}$$

$$\mu_{Far(t)} = \begin{cases} 0, & d \le 30 \\ \left(\frac{d-30}{10}\right), & 30 < d < 40 \\ 1, & d \ge 40 \end{cases}$$

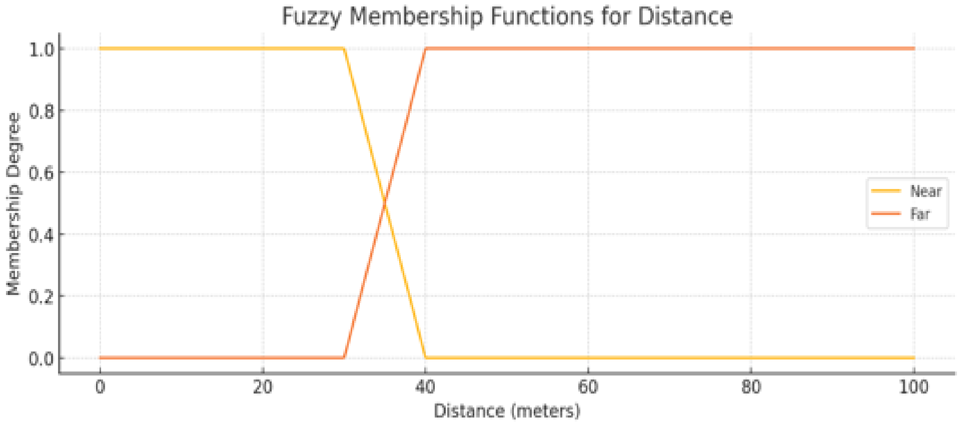

Figure 3. Fuzzy membership function for distance

d. Fuzzy Rule Base

Fuzzy rules implemented in the game:

1) IF (HP is Low) AND (Time is Short) THEN (Output is Run Direct)
2) IF (HP is Medium) AND (Distance is Near) Then (Output is Help NPC)
3) IF (HP is High) AND (Time is Long) Then (Output is Use APAR)
4) IF (HP is Medium) AND (Distance is Far) Then (Output is Help NPC)
5) IF (HP is Low) AND (Distance is Far) THEN (Output is Run Directly)

e. Inference Engine

The inference engine employs the Mamdani method, using the MIN operator for AND and MAX operator for OR. An example of Rule 1 is as follows:

$$\alpha\ predikat1 = \min\left(\mu Rendah(HP), \mu Pendek(Waktu)\right)$$

f. Defuzzification Process

The defuzzification process uses the Centroid method to generate a crisp output:

$$Output = \frac{(\Sigma\ \alpha i *\ zi)}{(\Sigma\ \alpha i)}$$

where:
αi = α-predikat value for the i rule
zi = output value for the i rule

The final output will be rounded to the nearest integer (0, 1, or 2) to determine the appropriate action to be taken.

Research Subjects

This study involves 43 respondents from various age groups and backgrounds to evaluate the effectiveness of the fire evacuation simulation game. In addition, the study also engages several expert validators, including: Game design experts, who will assess the quality and usability of the gameplay Educational experts, who will evaluate the game's potential as an effective learning tool.

Data Collection Techniques

In this study, data were collected using data collection techniques in the form of :

Observation

Researchers will observe how respondents interact with the game, including decision-making in fire situations, to assess the feasibility of the game design and its effectiveness.

Interviews

Interviews with experts and respondents will be conducted to gain deeper insights into the feasibility of educational content, game design, and overall user experience.

Questionnaires

Respondents will complete a questionnaire after playing the game to assess aspects such as understanding of fire evacuation procedures, ease of use, and whether the game provides an effective and efficient learning experience.

Table 1. Questionnaire items

No.	Question
1	This game helped me understand fire evacuation procedures.
2	The information in the game is presented clearly and easily understood.
3	The visual design of the game is attractive and realistic.
4	The in-game controls are easy to use and understand.
5	The in-game scenarios correspond to real-world fire conditions.
6	This game provides a fun and educational experience.
7	Decision making in the game helps me understand emergency situations.
8	The game duration is appropriate (not too long or short).
9	The scoring system helped me evaluate how well I made decisions during emergencies.
10	I would recommend this game to others to learn about fire evacuation.

Data Analysis Techniques

After data collection, the next step is to analyze the data to evaluate the feasibility of the developed product. The analysis process consists of the following stages:

Preparation

Researchers verify the completeness of respondent identities, validate the collected data, and ensure its relevance to the research criteria.

Tabulation

Each questionnaire item is scored using a Likert scale of 1 to 5, indicating the feasibility level of each product aspect. The scoring scale is as follows:

Table 2. Feasibility Scoring Scale for the Educational Fire Evacuation Game

Category	Score
Excellent / Highly Feasible	5

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Category	Score
Good / Appropriate / Feasible	4
Fair / Less Appropriate	3
Poor / Inappropriate	2
Very Poor / Highly Infeasible	1

Application of Data

After scoring, the total feasibility percentage is calculated using the following formula:

$$P = \frac{S}{N} \times 100\%$$

Where:
P = Feasibility percentage
S = Total score obtained
N = Maximum possible score
The feasibility percentage is then categorized as follows:

Table 3. Product feasibility criteria based on percentage

Feasibility Percentage	Category
81–100%	Highly Feasible
61–80%	Feasible
41–60%	Less Feasible
21–40%	Barely Feasible
< 20%	Highly Infeasible

These analytical results are used to determine whether the developed product meets the educational objectives and is acceptable for practical use.

3. RESULTS AND DISCUSSIONS

This study produced the educational game Fire Escape, a simulation designed to teach self-evacuation techniques during a fire. This game uses an interactive approach, so it can help children, teenagers, and parents who are still unfamiliar with dealing with fire emergencies. The Fire Escape educational game aims to help users learn evacuation routes and practice emergency procedures in a more engaging and accessible way. Developed using Unity 2022 and programmed in C#, the game leverages Unity's advanced graphics capabilities to create an immersive experience. C# is used to handle the game mechanics and player interactions. After development, the game was made into an APK file, allowing it to be installed and played on Android smartphones, making it easily accessible to a wide range of users.

Game Layout Chart

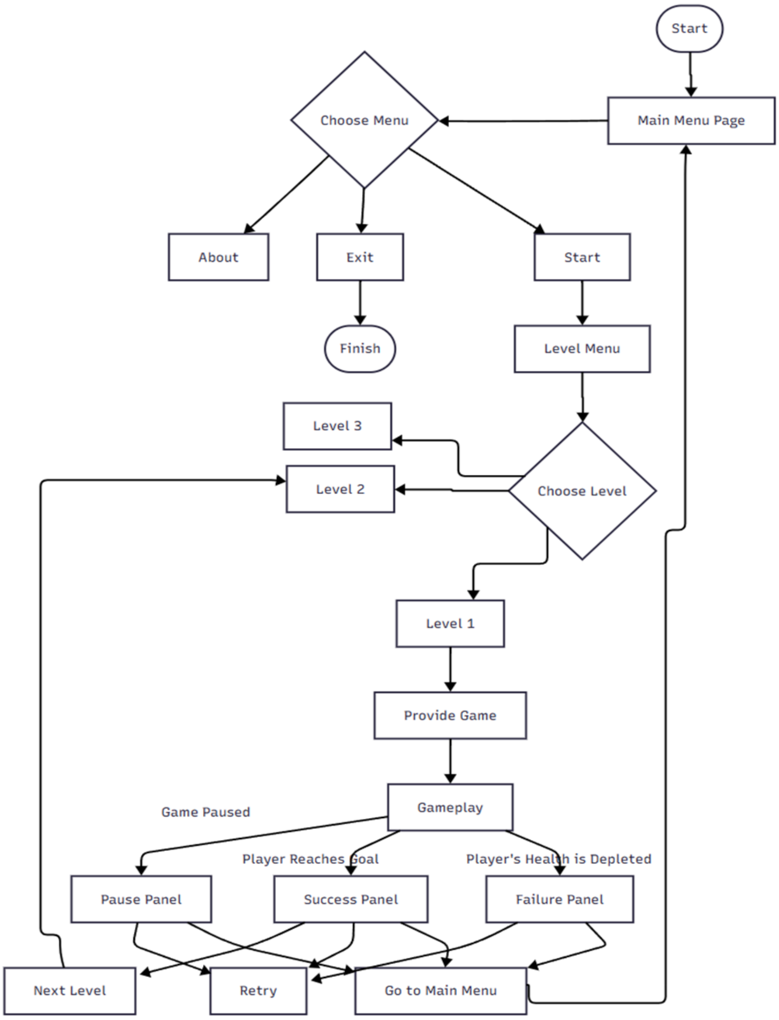

Figure 4. Offered three difficulty levels: level 1, level 2, and level 3.

Each level includes interactive gameplay elements, such as pausing the game, reaching the evacuation goal, or failing due to the depletion of the player's Health Points. Success allows the player to proceed to the next level, while failure provides the option to retry the level or return to the main menu. With its systematic design, this flowchart helps the development team ensure a logical storyline, facilitate testing, and enhance the player experience.

Game Characters

This study identified the characters used in the Fire Escape game, where each character plays a role that supports the gameplay scenario.

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Table 4. Game characters

Character	Role	Description
	Player	The main character controlled to complete the evacuation mission.
	NPC	A character that must be rescued by the player during gameplay.
	Enemy/Obstacle	Obstacles that can reduce Health Points or block the evacuation route.
	Fire Extinguisher	Equipment used to extinguish fires and open safe paths.

Storyboard

The player is in a hotel room when a fire breaks out, with flames beginning to fill the space. The goal is to escape the room safely, avoiding fire and debris, and finding the emergency stairs. Along the way, players can interact with various objects, such as doors that open after pressing an interaction button, fire that reduces HP if too close or exposed too long, NPCs (other guests) who can be rescued for bonus points, and fire extinguishers (APAR) to extinguish hallway fires to clear a safe path. Challenges include avoiding obstacles, deciding whether to assist NPCs, and finding a safe route to the emergency stairs within a time limit. Victory is achieved if the player safely reaches the stairs; failure occurs if time runs out or HP is depleted by fire exposure.

UI Display

The UI design of the game is intended to provide an attractive, intuitive user experience that supports interactive gameplay. The main displays in the game include

Splash Screen Display

Figure 5. Splash screen of "Fire Escape"

Displays the game name and Unity logo, offering a strong first impression.

Main Menu Display

Fire Escape Hotel is an educational game simulating fire disaster mitigation in a high-rise building. By integrating Fuzzy Logic, the game can process uncertain data such as fire intensity, smoke density, and occupant count to provide more dynamic scenarios. Players experience realistic evacuation, risk assessment, and adaptive evacuation routes based on current fire conditions. This approach makes the game entertaining and an interactive learning tool for fire mitigation.

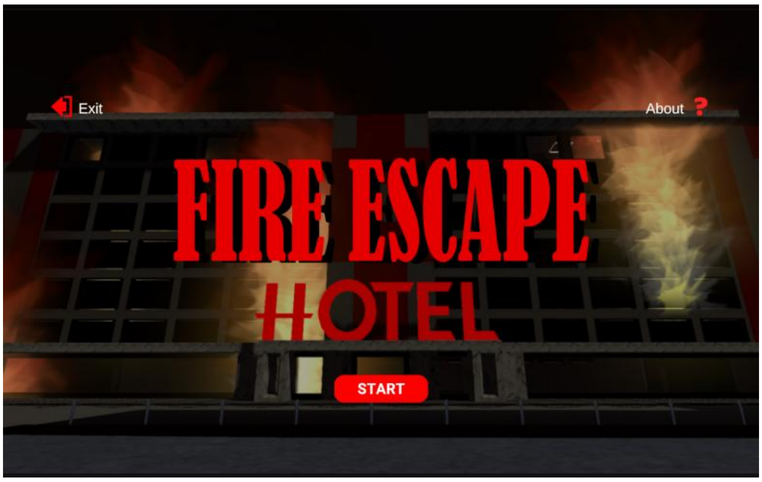

Figure 6. Main Menu of "Fire Escape"

Button options:
Start: Begin the game and select a level.
About: Display information about the game developer.
Exit: Exit the application.

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Level Menu Display

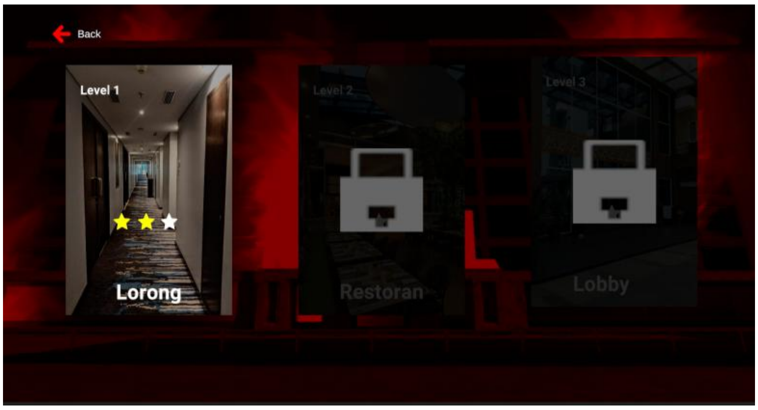

Figure 7. Level menu of "Fire Escape"

Players can select a level. Higher levels unlock after completing previous ones.

Gameplay Display

Figure 8. Gameplay controls of "Fire Escape"

Main elements:
HP Bar: Indicates player health.
Fire Extinguisher Bar (APAR): Shows fire extinguisher capacity.
Mission Info: Provides objectives.
Controls: Analog movement, jump, interaction, and pause buttons.

Using Fire Extinguisher Display

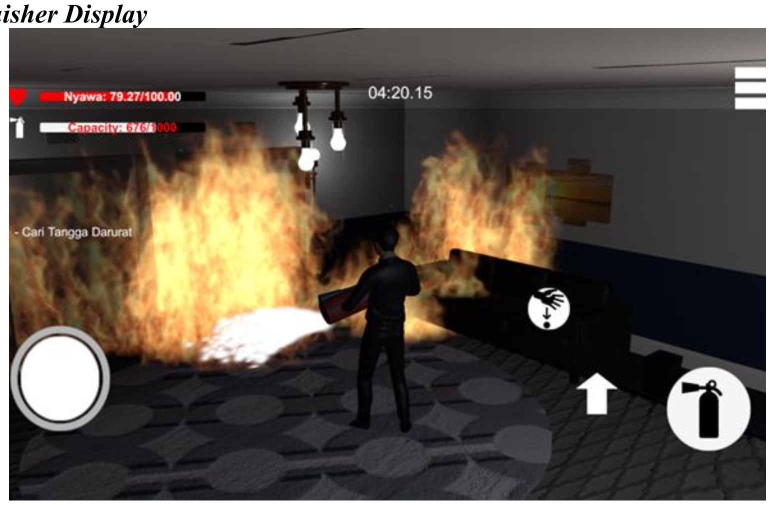

Figure 9. Using the fire extinguisher

Players can use the extinguisher to put out fires blocking evacuation routes. This teaches proper fire extinguisher use in emergencies, requiring players to aim correctly while avoiding direct contact with flames to maintain safety and health.

Carrying NPC Display

Figure 10. Carrying an NPC

Players can carry or guide trapped NPCs to safety. Rescuing NPCs gives bonus points and reinforces the importance of helping others during emergencies.

Pause Screen

Figure 11. Pause screen of "Fire Escape"

Allows players to pause the game, view objectives, resume, return to the main menu, or restart.

Failure Screen

Figure 12. Failure panel of "Fire Escape"

Offers options to retry the level or return to the main menu.

Success Screen
Players earn stars indicating success and are directed to the next level.

Figure 13. Success panel of "Fire Escape"

Fuzzy Logic Implementation

Below is a manual calculation using Mamdani fuzzy rules with the following inputs:
HP = 35 (max 100)
Time = 90 seconds (max 300 seconds)
Distance = 35 meters (max 100 meters)

a. Rule Definitions
   Rule 1: IF HP low AND time short THEN run directly (Output = 0)
   Rule 2: IF HP medium AND distance close THEN help NPC (Output = 1)
   Rule 3: IF HP high AND time long THEN carry APAR (Output = 2)
   Rule 4: IF time medium AND distance far THEN help NPC (Output = 1)
   Rule 5: IF HP low AND distance far THEN run directly (Output = 0)
b. Membership Function Calculations
   1) Membership Function
      a) HP (35)

$$\mu_{Low(35)} = \frac{40-35}{10} = 0.5$$

$$\mu_{Medium(35)} = \frac{35-30}{10} = 0.5$$

$$\mu_{High(35)} = 0$$

      b) Time (90s)

$$\mu_{Short(90)} = \frac{100-90}{20} = 0.5$$

$$\mu_{Medium(90)} = \frac{90-80}{20} = 0.5$$

$$\mu_{Long(90)} = 0$$

      c) Distance (35m)

$$\mu_{Near(35)} = \frac{40-35}{10} = 0.5$$

$$\mu_{Far(35)} = \frac{35-30}{10} = 0.5$$

   2) Fuzzy Inference
      Rule 1:
      IF (HP is Low) AND (Time is Short) THEN (Output is Run Directly)

$$\alpha 1 = \min(\mu_{Low(35)}, \mu_{Short(90)}) = \min(0.5, 0.5) = 0.5$$

Output = Run Directly (z1 = 0)
Rule 2:
IF (HP is Medium) AND (Distance is Near) THEN (Output is Help NPC)

$$\alpha 2 = \min(\mu_{Medium(35)}, \mu_{Near(35)}) = \min(0.5, 0.5) = 0.5$$

Output = Help NPC (z2=1)
Rule 3:
IF (HP is High) AND (Time is Long) THEN (Output is Carry APAR)

$$\alpha 3 = \min(\mu_{High(35)}, \mu_{Long(90)}) = \min(0, 0) = 0$$

Output = Carry APAR (z3 = 2)
Rule 4:
IF (Time is Medium) AND (Distance is Long) THEN (Output is Help NPC)

$$\alpha 4 = \min(\mu_{Medium(90)}, \mu_{Long(35)}) = \min(0.5, 0.5) = 0.5$$

Output = Help NPC (z4 = 1)
Rule 5:
IF (HP is Low) AND (Distance is Long) THEN (Output is Run Directly)

$$\alpha 5 = \min(\mu_{Low(35)}, \mu_{Long(35)}) = \min(0.5, 0.5) = 0.5$$

Output = Run Directly (z5 = 0)

3) Defuzzification

$$Output = \frac{(\Sigma\ \alpha i * zi)}{(\Sigma\ \alpha i)}$$

$$Output = \frac{(0.5 * 0 + 0.5 * 1 + 0 * 2 + 0.5 * 1 + 0.5 * 0)}{(0.5 + 0.5 + 0 + 0.5 + 0.5)}$$

$$Output = \frac{(0 + 0.5 + 0 + 0.5 + 0)}{2} = \frac{1}{2} = 0{,}5$$

4) Final Decision

Since the result is 0.5 (closer to 0), the system recommends “Run Directly” due to the low HP and limited time, prioritizing self-rescue.

Research Results

The feasibility of the Fire Escape simulation game was evaluated through a questionnaire distributed to respondents after playing the game. The questionnaire consisted of 10 items rated on a Likert scale. Here is a summary of the results:

Table 5. Respondent feedback recap for the “Fire Escape” game

No.	Evaluate Indicator	Measurement Scale					Percentage
		1	2	3	4	5	
1	Helped me understand fire evacuation procedures	0	1	4	25	13	83.26%
2	Information is clear and easy to understand	1	0	9	11	22	84.65%
3	Visual design is attractive and realistic	1	2	4	16	20	84.19%
4	Controls are easy to use and understand	0	0	7	13	23	87.44%
5	Scenario aligns with real-life fire conditions	0	0	7	19	17	84.65%
6	Game is enjoyable and educational	0	1	4	15	23	87.91%
7	Decision-making helped me understand emergencies	0	0	4	23	16	85.58%
8	Game duration is appropriate	0	0	6	21	16	84.65%
9	Scoring system helps evaluate decisions	0	0	5	15	23	88.37%
10	I would recommend this game to others	0	1	4	20	18	85.58%
	Total						856.28
	Average Percentage						85.628%
	Category						Highly Feasible

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The feasibility evaluation of the Fire Escape simulation game, using a 10-point Likert-based questionnaire, showed an average score of 85.63%, categorised as "Highly Feasible." Nearly all aspects—from understanding evacuation procedures, clarity of information, visual design, ease of control, scenario suitability, educational value, game duration, scoring system, and user recommendations—scored above 83%. This indicates that the game is effective and suitable as a learning tool for fire mitigation.

This study focuses on the development of a 3D educational simulation game “Fire Escape”, designed to help users understand and practice fire evacuation procedures, especially in high-rise buildings such as hotels. The integration of 3D graphics technology through Unity 2022, combined with C# programming, allows this game to deliver a more immersive learning experience compared to conventional educational methods, which are often static and less stimulating. The interactive simulation model adopted in the game encourages players to actively participate in decision-making processes, closely mimicking real-life emergency scenarios while equipping them with essential self rescue skills.

One of the best aspects about this project is that it uses the Mamdani fuzzy logic system. This method is supposed to help players figure out what to do next by looking at factors like their health level (HP), how much time they have remaining, and how far they are from evacuation sites or other vital targets. This strategy makes the game more realistic and responsive, which makes it better at simulating how people would leave a fire.

But there are still some technical problems that need to be fixed. It’s necessary to change the game’s difficulty level so that players can follow safety guidelines, but further testing is needed to make sure that the game scenarios meet the rules for evacuating a building in case of fire. Performance optimization is also important to make sure the game performs smoothly on a lot of various platforms with different hardware specs.

It is also important for this study to involve people of all ages, as this kind of diversity can give us useful information about how well the game works as a way to learn. Players are meant to learn more about how to deal with fire situations by using progressive learning scenarios and interactive aspects like using fire extinguishers and helping non-playable characters (NPCs).

4. CONCLUSION

This study successfully made and used an educational game called “Fire Escape”, which is a new way to learn how to get out of a multi-story building in case of a fire. Using interactive 3D simulations that are very similar to real-life situations helps players learn how to save themselves better. This game is aimed to help people learn more about and be ready for any fires.

. The implementation of fuzzy logic provides an adaptive decision-making system based on player conditions, such as health (HP), time, and distance, so that the gameplay becomes more dynamic and responsive to various emergency situations. The intuitive interface design and control mechanism make it easy for players to operate the game, providing an experience that is easy to understand for all ages.

Multilevel scenarios and interactive features in the game, such as the use of fire extinguishers (APAR) and NPC rescue, support the learning of evacuation procedures effectively and provide practical knowledge in dealing with real fire situations. The star-point system further motivates players to learn proper safety protocols.

For future improvements, enhancing interactivity by adding NPCs that give hints and adjusting difficulty levels for various age groups is recommended. Additional learning features like evacuation tutorials should be considered. Moreover, broader testing involving more respondents and collaboration with relevant institutions will enhance the effectiveness and credibility of the game as an educational tool.

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